

THESIS

EFFECTIVE STRATEGIES TO REDUCE THE IMPACTS OF SKILLED WORKER
SHORTAGES IN THE CONSTRUCTION INDUSTRY

Submitted by

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ABSTRACT

EFFECTIVE STRATEGIES TO REDUCE THE IMPACTS OF SKILLED WORKER SHORTAGES IN CONSTRUCTION INDUSTRY

One of the most common problems over recent years in the construction industry is the supply of skilled workers to the industry. Across the United States, over the years this has been identified repeatedly. During the great recession, many of the unemployed workers shifted into the more stable industries. In the recent years, baby boomer generation (born 1946 to 1965) retirement and a decrease in unemployment rates indicate a skilled workforce shortage in the United States. Skilled workforce shortages have some impacts on the industry. These impacts could be reduced by training the new low skilled workers coming into the industry. However, there has been limited research to identify the strategies that can be implemented during the design and planning stage.

This thesis reports the results of interviews with eight industry professionals and explored their view on each impact identified during the literature review. The researchers collected participant responses through convenience sample interview questionnaire to identify the strategies used and suggested by the participants. Through this qualitative study, it was expected that a list of suggested and current strategies towards the impacts would emerge. This data was then used to create a structured survey to find the effectiveness of the strategies identified through the interviews. The researchers collected participant responses with structured electronic survey through random sampling of the Design Build Institute of America.

The results indicated the majority of the participants thought prefabrication could be the most efficient way to reduce the negative impacts on the construction industry. Both qualitative

and quantitative results emphasized the shift towards prefabrication can be more efficient than any other strategies identified.

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CHAPTER 1: INTRODUCTION

Introduction

The construction industry consists of complex organizations experiencing swift changes, with diversified offerings, that are widely distributed and require a variety of skilled units. One of the major challenges in the construction industry includes recruiting and passing critical knowledge to the next generations (Sowers & Woody, 2006). The problem has been identified and surveyed by various researchers and found to be one of the important and ever-increasing problems in the construction industry (Burleson, Haas, Tucker, & Stanley, 1998; Darren & Mark, 2012). There have been multiple reasons for worker shortages in the industry, including retirement and workers moving out of the industry.

There are existing initiatives to reduce the impact of skilled worker shortages, but most of the research has focused on increasing the skill levels of the existing workforce through training (Albattah, Goodrum, & Taylor, 2015). Research exploring the impact of the possible changes during the design phase has been limited. Since there has been limited research in this area, the focus of this research was aimed to explore and report what strategies are used by designers and contractors to counter the impacts due to the skilled workforce shortages in the construction industry. This research was oriented towards studying the strategies used in the design phase or before construction phase to reduce the impacts using the designers and contractors' perspective. With the limited research on the specific topic, researchers aimed to first provide a background of the problem and explain the need for research.

1.1 Purpose of the Study

The purpose of this study was to explore and record the various strategies used by the designers and contractors to reduce the impact of skilled workforce shortages in the construction industry. To accomplish this objective, a multi-method research plan was developed. Phase I utilized qualitative telephone interviews administered among the industry professionals with experience. The interview was partially structured with some questions left open for discussion to gather more data. After gathering the data from the interviews, Phase II utilized an on-line survey tool to explore the effectiveness of the strategies identified through the qualitative analysis. This study sought to explore the effective strategies among the ones identified. By utilizing this data, the industry can be more focused and reduce the impact of skilled workforce shortages on projects.

1.2 Research Questions

1. What are the strategies used by the designer/contractors before construction phase to reduce the impacts of skilled workforce shortages in the construction industry?
2. What are the most effective strategies amongst the identified strategies?

CHAPTER 2: LITERATURE REVIEW

Introduction:

Skilled workforce shortage in the construction industry can have significant implications on the market. In the United States, the problem of skilled labor shortage has been persistent since the recovery began in 2011. Because of the skilled labor shortages, more low skilled workers are being employed in the construction industry. Hence, skilled workers shortage had an impact on quality and productivity of construction to some extent (Dai, Goodrum, & Maloney, 2009). This literature review notes the impacts of skilled worker shortages in the construction industry. Studying the most common impacts occurring due to low skilled workforce contributed to understanding different ways adopted by designers and contractors to reduce the impacts. First, the current state of skill shortages in the construction industry is reviewed to understand the importance of the issue. Next, various impacts on the construction industry were reported to strengthen the need for the research.

2.1 Construction craft workers shortage

2.1.1 History of shortage

Skilled workforce shortage has been a recurring problem for decades in the United States construction industry. The problem has been identified and surveyed by various researchers and found to be one of the important and ever-increasing problems in the construction industry (Burleson et al., 1998; Darren & Mark, 2012). It is identified that recruiting new generations into

construction industry is quite difficult in both developed and developing countries (Wells, 2001). This was supported by a survey conducted by Rosenbaum (2001), where 78% of the respondents attributed the increase in the shortage of skilled construction craftsmen over past three years to low entry-level participation. In a similar survey conducted by Sawyer and Rubin (2007) reported, 78% of respondents agreed on the increase in shortages. Similarly, many other surveys indicate the shortages are gradually growing in recent years (Gonzales, 2013; Levanon, Cheng, & Pattera, 2014). The rapid drop in unemployment rate in recent years and retirement of baby boomer generations born between 1946 and 1965 is indicating the risk of labor shortages in the United States (Levanon et al., 2014; Mackenzie, Kilpatrick, & Akintoye, 2000). Figure 1 shows the decline in unemployment rate in construction industry starting in the year 2010. In continuation of this, Bureau of Labor Statistics (2015b) statistics indicated that annual rate of change has shifted from -1.7 percent to 2.6 percent in the periods 2002-2012 to 2012-2022 respectively. A survey conducted by Taylor, Karimi, Goodrum, and Albattah (2016) among North American construction companies reported that 52% of surveyed projects experienced a shortage of skills. The growth of construction industry has raised concerns among stakeholders due to lack of skilled construction labor to support. Because of the difficulty in finding qualified workers, more low skilled workers were being employed impacting the industry. In addition, retention rates of employees gradually decreased due to lack of skills(Ilozor, Okoroh, & Egbu, 2004).

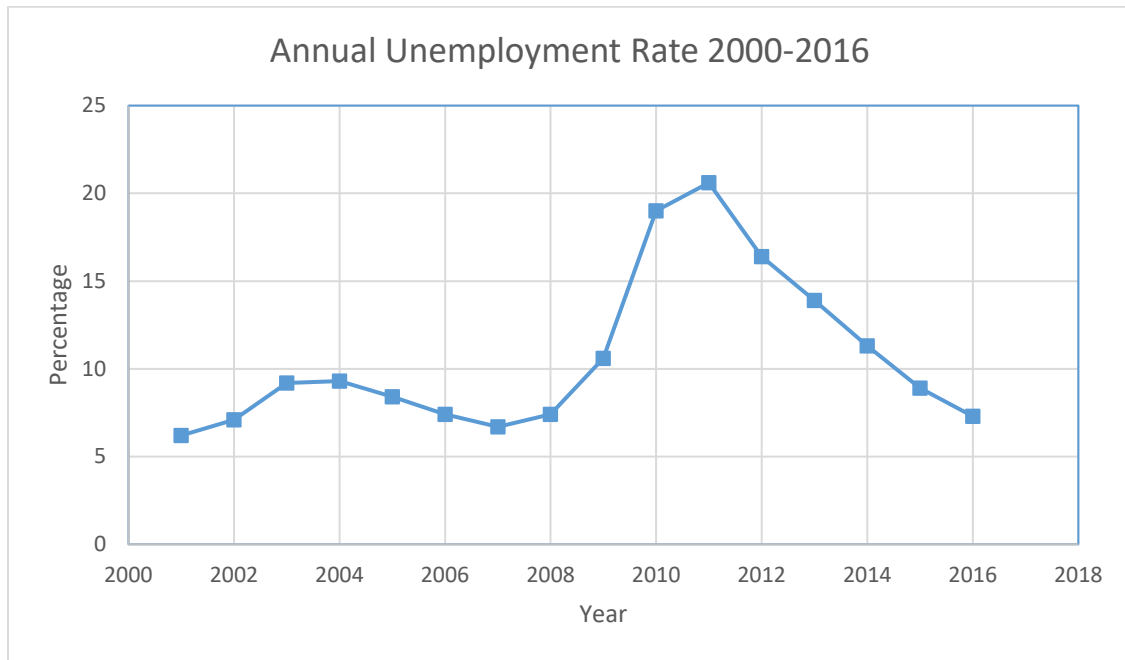


Figure 1: Average Unemployment Rate in Construction Industry from 2000-2016

Source: US Bureau of Labor Statistics

2.1.2 Causes of a skilled worker shortage

One of the most common problems over the years in the construction industry is the supply of skilled workers to the industry. There have been explanations on how the different factors contributed towards decreased skill levels in workers. The broad cause accepted for the shortage is difficulty in recruiting replacements into the industry (Darren & Mark, 2012). Other major causes identified for shortages by researchers are aging workforce, a low attraction of youth towards construction, and lack of training for evolving skills requirements (Barnow, Trutko, & Piatak, 2013; Dainty, Ison, & Briscoe, 2005; Tucker et al., 1999). Money is considered to be one of the major motivation for people to work (Jurgensen, 1978); it provides security, sustenance, and privilege (Judge, Piccolo, Podsakoff, Shaw, & Rich, 2010). Construction industry lacks stable employment and also has lower starting wages which are demotivating the youth (Goodrum,

2003). Albattah et al. (2015) represented causes of skill shortages as explained by existing researchers as shown in Table 1.

Table 1: Demographic Influences on Construction craft Shortages In The U.S. And Canada,
Source: Albattah et al. (2015) in

Reason of Construction Workforce Shortages	Reference(Previous studies)
Aging of the Workforce	Watson 2007; Komamickim2012; Gonzales 2013; Wilder 2013; Fujita 2014
Increase the demand of craft workers	Watson 2007; Healy et. Al. 2011; Shah and Burke 2005; Haskel and Martin 1993; Komamicki 2012; Galvin 2013; Wilder 2013; Shelar 2013
Changing in skill requirements(i.e. new technology) Poor education/Poor training	Watson 2007; Haskel and Martin 1993
Poor Education/ Poor training	Watson 2007; Healy et. al. 2011; Haskel and Martin 1993; Castaneda et. al. 2005
Decrease the number of the new entrants	Druker and White 1996
Poor wages	Watson 2007; Shah and Burke 2005; Haskel and Martin 1993; Castaneda et. al. 2005; Healy et. al. 2011; CII 2000
Poor industry image	Shah and Burke 2005; Castaneda et. al. 2005
Poor working condition	Shah and Burke 2005; Castaneda et. al. 2005; CII 2000
Geographic location of business/job	Healy et. al. 2011; Shah and Burke 2005
Lack of job security/Poor treatment/ Poor safety	CII 2000
Lack of a worker-oriented career path	Castaneda et. al. 2005

2.2 Impacts on Industry

2.2.1 Productivity

The term “productivity” indicates the relation between output and associated inputs, generally expressed in cost (Yi & Chan, 2013). Values for input and output depends on the type of industry and specific work. For example, concreting could be measured in cubic meters per hour, whereas steel work is measured in linear meters per hour. Being relative in nature, it is difficult to trace it as an absolute value or benchmark productivity goals in construction (Allmon, Haas, Borcharding, & Goodrum, 2000).

2.2.1.1 Labor productivity in construction

There is no industry level isolated measure for labor productivity due to variations in output measurements and accounting procedures utilized in the construction industry (Bureau of Labor Statistics, 2014; Oglesby, Parker, & Howell, 1989). Unique and non-repetitive processes made it difficult to develop a standard method to measure labor productivity (Sweis, 2000). A widely used method of measuring labor productivity in construction is hourly output (A. Hanna, Chang, Sullivan, & Lackney, 2008; Thomas & Yiakoumis, 1987). This method includes a number of hours worked by workers as input and physical quantity of work completed as output. Even though there is no standard assessment and single opinion about the trends of productivity, it is generally accepted that level of construction productivity has not kept pace with other industries in the US (Goodrum, Haas, & Glover, 2002; Tuchman, 2004). Craft workers play a significant role in labor productivity as they execute the construction activities (Jarkas, 2010; Liu & Ballard, 2008; Maloney, 1983). Being the key player in executing the activities in the construction industry, construction craft workers influence the overall productivity of the project significantly (Dai,

Goodrum, Maloney, & Sayers, 2005; Maloney, 1983). Considering typical project margins of 2-3% of total project cost, labor cost and productivity management are critical to the financial success of a construction project (A. S. Hanna, Taylor, & Sullivan, 2005). Similar to the above arguments, Liu and Ballard (2008) stated that labor productivity can impact the financial success of a project. Understanding relationship between labor productivity and human factors related to it can improve overall productivity (Liberda, Ruwanpura, & Jergeas, 2003).

2.2.1.2 Causes of low productivity

There has been a lot of research identifying the causes of low productivity in the construction industry by many researchers (Borcherding & Garner, 1981; Diekmann & Heinz, 2001; Horman & Thomas, 2005). Many researchers focused on different factors influencing productivity. For instance, Koehn and Brown (1986) reported labor as the second most important factor which included the level of skills in craft workers. Liberda et al. (2003) prioritized human factors affecting the productivity on job site. Experienced industry experts ranked worker experience and skills highest on the list of human factors.

A study by Borcherding and Garner (1981) studied factors affecting productivity and ranked them in the following order; (1) material availability; (2) tool availability; (3) work redone; (4) overcrowded work area; (5) inspection delays; (6) foreman incompetence; (7) crew interference; (8) craft turnover and absenteeism; and (9) foreman changes. The first two factors could be avoided by better management strategies and being major influencing factors, researchers investigated ways to minimize their impact (Allmon et al., 2000; Borcherding, Samelson, & Sebastian, 1980; Diekmann & Heinz, 2001; Shehata & El-Gohary, 2011). Other factors have an underlying common latent cause; lack of training or skills. A study by Olsen and Tatum (2014) revealed that lack of skilled labor caused higher project cost and lower productivity. It can be noted

that tools, machinery, and modified skill requirements for the construction craft workers (Hewage, Ruwanpura, & Jergeas, 2008) can possibly reduce productivity.

One of the recent studies by Dai, Goodrum, Maloney, and Srinivasan (2009) used 83 productivity factors to conduct a survey of craft workers. As any construction activity would have multiple impact factors, survey results were used to conduct a factor analysis to extract latent primary factors. Results highlighted that worker qualification was next to equipment and management to have the highest potential for improvement (Dai, Goodrum, Maloney, et al., 2009).

2.2.2 Defects in Structure

There are many definitions used in existing research for defects (Forcada et al., 2012; Ilozor et al., 2004; Mills, Love, & Williams, 2009). A definition by Watt (2007, p. 96) explains defect as *“failing or shortcoming in the function, performance, statutory or user requirements of a building, and might manifest itself within the structure, fabric, services or other facilities of the affected building”*. Defects in construction can be caused due to design, maintenance issues, faulty drawings, materials, equipment, specifications, or workmanship (Assaf, Al-Hammad, & Al-Shihah, 1996). Many researchers determined through surveys and expert opinions that design and management errors contribute much higher defects in construction than lack of skills in craft workers. These design and management related causes could be rectified at the design and mobilization stages. A large number of complaints are recorded at handover although there are many systems to detect and eliminate defects (Chong & Low, 2005). Defects occurring due to construction workers are rebuilt or they remain without rectifying. Rework affects the schedule and budget of the project; and if left, they become latent defects (Chong & Low, 2005; Qazweeni & Daoud, 1991).

Forcada et al. (2012) identified most common defects occurring post-handover and stressed on a strong correlation between defects and the people who are carrying out the construction on site. Authors also identified that defects that are left without rectification are difficult to identify in early stages of building a life. They appear mostly after some years of functioning and have a primary effect on the reputation of contractors (Forcada et al., 2012). For example, tools thrown on the finished floor can lead to cracks. Problems like this cannot be identified in early stages of the building life.

2.2.3 Reworks

Various terminologies have been used in the previous literature to denote rework but are similar in overall perception. For instance, Burati, Farrington, and Ledbetter (1992) described it as quality deviations. Josephson and Hammarlund (1999) used the term defect and Barber, Graves, Hall, Sheath, and Tomkins (2000) interpreted it as the quality failure. Rework was defined as the activities that have to be done more than once or activities that remove work previously installed as part of a project by Rogge (2001).

Rework in construction has an adverse effect on construction time and cost. Borcharding, Palmeter, and Jansma (1986) reported rework as one of the five major categories of loss of productivity. A recent research by Rivas, Borcharding, González, and Alarcón (2010) also highlighted that the importance of rework is ranked just after materials as a major factor influencing productivity (Rivas et al., 2010).

2.2.3.1 Cost of Rework:

The cost of rework has been examined in previous research and it was found to be as high as 25 percent of the contract value (Barber et al., 2000). A survey by Burati et al. (1992) on nine

major engineering projects indicated that on average, 12.4 percent of contract value is spent for correcting deviations from specifications. Josephson and Hammarlund (1999) reported the cost of rework in the construction of residential, industrial and commercial projects ranged from 2 to 6 percent of their contract value. Love and Li (2000) in their research found the rework cost to be 3.15 and 2.40 percent of the contract value in residential and industrial projects respectively. A highly competitive industry like construction reduces the profit margin and small variations in estimations can prove to be highly important. Hence, by reducing the unexpected costs like rework can improve the profitability of contractors.

2.2.4 Safety in construction

The construction industry is considered a risky industry due to the high incidence rate of work-related injuries and fatalities. According to Bureau of Labor Statistics (2015a), a total number of work-related fatal injuries recorded in the U.S was 4821 in 2014, and 899 of the total were recorded in the construction industry. This data also highlighted the fact that the likelihood of being killed on job site is four times higher than any other industry. Carr (2008) in a research found that employees with one year or less experience have the highest fatality rate on construction sites. Young, less-educated and non-English speaking low-skilled workers are more vulnerable to accidents in the construction industry (Anderson, Hunting, & Welch, 2000; Dong, Fujimoto, Ringen, & Men, 2009). According to Sawacha, Naoum, and Fong (1999), vulnerability is least for the most experienced and young, unskilled workers are least aware of safety requirements. Choudhry and Fang (2008) also noted that experience has a substantial role in the unsafe behavior of construction workers on site. This indicates having unskilled workers on site affects construction site safety negatively.

CHAPTER 3: RESEARCH METHODOLOGY

Introduction

The purpose of this chapter is to present the methodology used in this research. As mentioned in chapter one, this research is oriented towards studying the strategies used by designers and contractors to reduce the impact of skilled worker shortages on construction projects. The framework consists of two main steps, qualitative and quantitative. Both qualitative and quantitative research designs, also known as the mixed method, was adopted as a research methodology for this research. A mixed method approach strengthens the research since both qualitative and quantitative data are analyzed (Creswell & Clark, 2007) . In chapter 2, impacts of unskilled workers were identified based on the existing literature. Since the literature on strategies used by designers to reduce the impacts of skilled worker shortages is limited, a qualitative approach was identified to be more appropriate as Phase 1 of the research. This qualitative method helped in identifying the strategies employed, which would support the development of the survey questions to ask for the quantitative method. A survey questionnaire was developed as the quantitative method to understand the effective strategies for each impact identified in the qualitative method. This mixed method was utilized in triangulating data, a method to pursue convergence of data (Jick, 1979). These two methods can be noted further as Phase 1 and Phase 2.

3.1 Phase 1: Identification of Strategies to Reduce the Impacts

The first phase of research was a qualitative method carried out through interviews with designers and contractors to understand the strategies they were practicing to reduce the impacts

of shortages in a skilled workforce. Interviews started with a brief background of the shortage of skilled workforce to familiarize the participants with the research topic. This was followed by a quick introduction to impacts of the skilled workforce shortages in the construction industry. Later, it was followed by the questionnaire prepared to understand their strategies. The questionnaire was semi-structured but consisted of some open-ended questions that helped in deriving direct questions for the survey in Phase 2. This method allows getting a better understanding of the topic and different views on the topic from the members (Hennink, 2007). Valid perceptions from member experience were be recorded after discussion. A copy of the questionnaire is included in the Appendix 1.

A nonrandom, convenience sampling of designers and contractors was identified based on availability and approachability for the interviews. All the participants were requested to share their experience and suggest some strategies to reduce the impact of skilled workforce shortage. Through the discussion, participant's perceptions of what could and will reduce the impact of shortages in the skilled workforce were recorded. After the discussion, each participant validated the data gathered through member checking of interview transcripts.

3.2 Phase 2: On-line Survey of Effective Strategies

To generalize the findings from the phase one to a larger population, a statistical analysis of a larger group of population is required. An electronic survey was developed to collect the data from a larger population. The survey consisted of a structured questionnaire to reduce the variance. The survey was distributed electronically, as it allows distributing a survey to a larger group of people. Questions in the questionnaire were framed using the strategies identified in the phase one of the research. The instrument was pilot tested to understand the reliability of the questions. One of the questions was repeated with a restructured sentence for identifying the quality of each

response. Those responses were eliminated from the results to avoid unwanted measurement error. Respondents were requested to participate voluntarily to share their perspective on each question.

Typical questions were in the following format with the impact and a strategy changing among each question.

eg. How effective can “Pre-fabrication” be to increase the “productivity” in low skilled workers?

1. Very Ineffective
2. Ineffective
3. Somewhat Ineffective
4. Neutral
5. Somewhat Effective
6. Effective
7. Very effective

3.3 Data Sampling

3.3.1 Target Population - Phase 1:

Creswell (2009) discusses the importance of purposefully selecting individuals for a qualitative study. He further asserts that the meaning of a qualitative research study is yielded when the participants are purposefully selected individuals – this assists the researcher in comprehending the research question better. A nonrandom, convenience sampling of designers and contractors was identified based on availability and approachability for the interviews. A pool

of industry experts was chosen and emailed for consent. Panel members consisted of designers and contractors with minimum experience of 12 years. Establishing a minimum experience level for the participants facilitated utilization of their experience in adapting to the shortage of skilled workforce in the recent years. A total of eight members were interviewed. Background of each member was recorded and reported in the research.

3.3.2 Target Population - Phase 2:

The study population selected was architects and contractors with design-build experience. Since the focus of the topic is on the strategies at the design and pre-construction phases to reduce the impact of skilled worker shortages, architects and contractors with experience can be a valuable source for the research. With increasing design-build projects, the contractor is involved during the design phase and knowledge of construction methods is shared (Uhlik & Lores, 1998). Hence, collecting the responses of contractors with design-build experience was also a valuable source. The survey was distributed to members of the Design-Build Institute of America (DBIA)

3.4 Measurement and Analysis

The use of interviews and electronic survey for research method is a reliable method for data collection and validation (Stewart, Shamdasani, & Rook, 2006). This allowed validation of the data collected during the interviews using a larger sample. According to Creswell (2013), data analysis in qualitative data requires reducing data into various forms of representation or discussion. The first phase of the research included interviews to explore the strategies to reduce the impact of skilled workforce shortages on construction. This discussion was recorded using audio tape along with written notes to review the discussion suggested by Creswell (2013) underlining any noteworthy statements and or speech marks that communicate an understanding

of how the participants experienced the phenomenon by browsing through the data collected; a process called horizontalization.

After the interview, a written summary of the data collected was shared with the interviewees to confirm their accuracy after transcription. The recordings were processed multiple times to take notes of the data missed in the hand notes recorded during the interview. Microsoft Excel was used to do the pattern analysis and each participant was given an identification number to avoid reporting personal identity. Strategies suggested by each interviewee for each strategy were grouped along with the participant number. After full understanding of recordings and responses from multiple participants, similar responses were grouped together. A sufficient number of patterns were identified in the grouped responses. The data was condensed into a tabular matrix according to the repetitive themes. This matrix was shared with another researcher to come to a reasonable acceptance of the responses and grouping. All the strategies mentioned by the participants with at least three repetitions were chosen to create the survey for phase 2. This process helped in identifying the strategies mentioned by the participants with reasonable repetition and acceptance among researchers.

The second phase of the research includes an electronic survey to understand the effectiveness of each strategy from a larger group of people. An experienced researcher evaluated survey instrument for the ease of understanding. The survey was pilot tested multiple times to review and the test survey responses were deleted. During review and revisions, the possible different understandings of questions were identified and replaced. There was a possibility of differences in the responses from designers and contractors, so collecting some demographic data with each survey helped to understand the variance recorded. All the responses were recorded on a Likert scale of seven points from agreement to disagreement.

All the data received through the survey was exported into Microsoft Excel to analyze. Exported data contained unintended data like the time it took for each participant and the time opened. All unwanted details collected by the survey website were deleted. Arithmetic mean aided the analysis of the responses to each question.

CHAPTER 4: RESULTS AND DISCUSSION

Measurement

This chapter presents the findings from both the phases of data collection along with the discussion. As mentioned in Chapter 3, the data required to answer this question was obtained from two phases of data collection as presented in the following sections.

4.1 Phase 1 Interviews

Eight individuals participated of the ten initially contacted through e-mail. As seen in Figure 3, there are people from different disciplines including design, onsite management, owner's and engineers. There are three architects, one engineer, two general contractors and two owners. Since this part of the research is qualitative, the interviews are the main source of data where participants are sharing their experience and suggestions with what they have been through and what they intend to do for reducing the impacts of skilled worker shortage. Since the research objective is to find the effective strategies prior to construction, it was chosen to have broad representation of project roles among the participants to get data that are more relevant. Figure 4 explains the primary industry they are associated with in the construction industry.

All the participants have been involved in preconstruction phase in their past experience in construction industry as shown in Figure 5

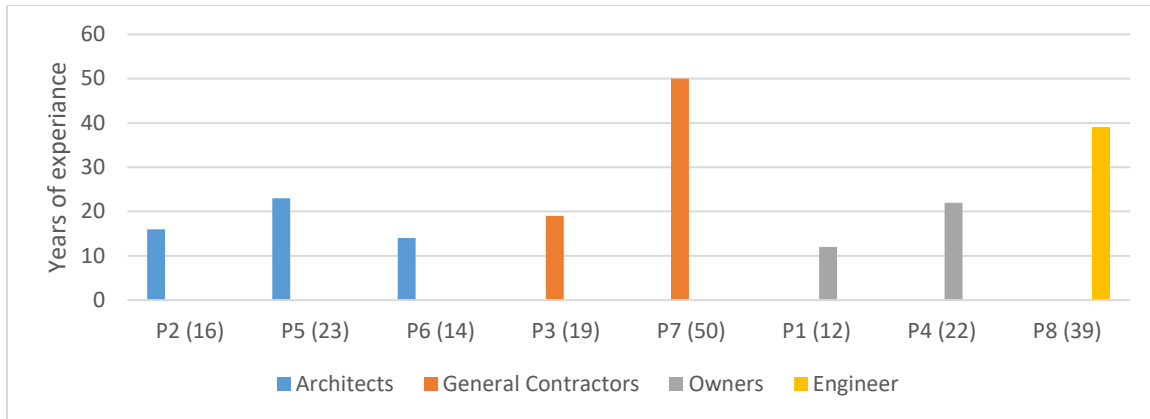


Figure 2: Experience of participants in the construction industry

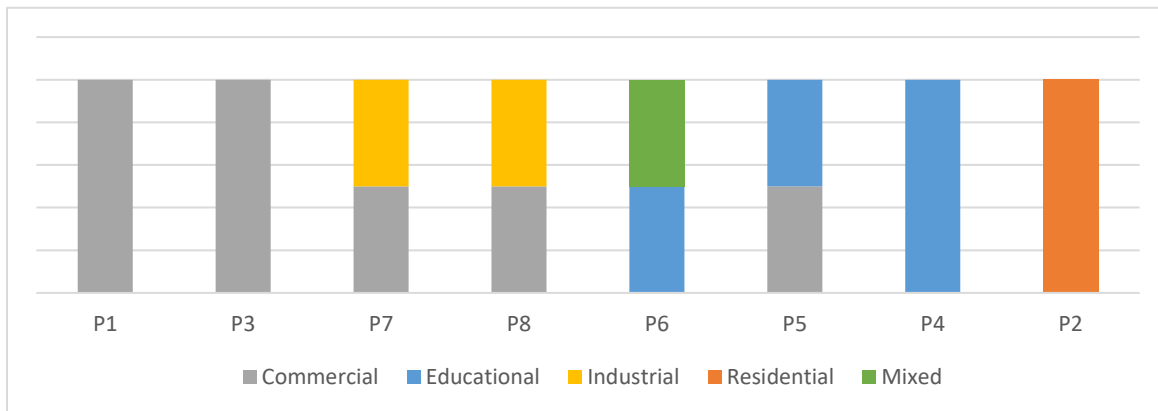


Figure 3: Primary industries of participants

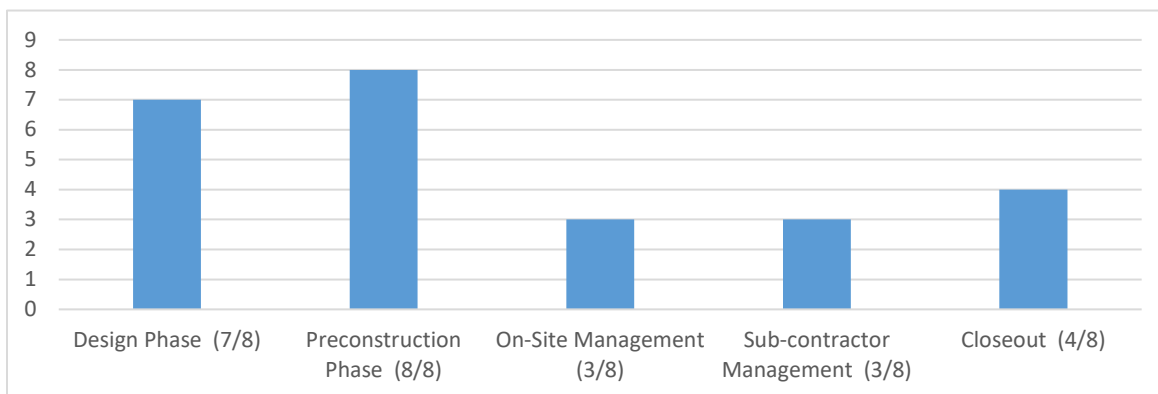


Figure 4: Number of participants involved in each phase of construction

All participants were read a short script informing of their rights as interviewees (see Appendix 2) prior to their respective interviews. Clear explanation about voluntary participation was given and choice to stop participating at any point without penalty was explained. All participants gave their consent to participate in the interview. All participants were asked the same set of questions about their background data. A brief description of research and topic was given to the participants to familiarize the expectation for the interview. Structured interview questions were used to start the interview. This not only helped to gain a profound understanding of the topic but also helped to understand the participants view on each impact. Topic related questions were asked in the same format with each participant. To the end, the open-ended questions were asked in such a way to get the participants perspective of actual intention for the previously mentioned responses. These questions helped in understanding, expanding and exploring strategies used which were not clearly stated in the structured part of the questionnaire.

4.2 Results of Interviews

The initial step for analysis was to gather usable data from interview responses. The steps followed to identify the strategies expressed in the discussions are described in Figure 6.

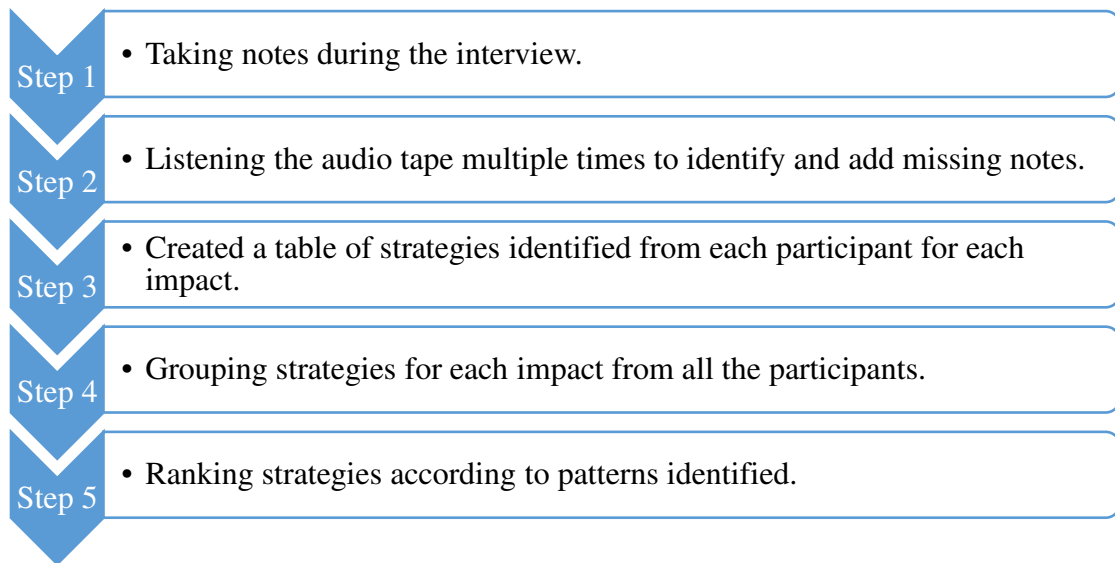


Figure 5: Process of interview analysis

Detailed analysis for Productivity is reported to show the process followed. The same method was followed for all the impacts identified.

4.2.1 Productivity

The first topic related question was *“We have identified through literature that skilled worker shortages can cause a decrease in productivity. Have you seen that and if so what strategies have you used to improve productivity?”*

This question was aimed to understand if the participant identified that the skilled worker shortages have an impact on productivity, and what strategies were being implemented to address the situation. Interestingly, everyone was experiencing a decrease in onsite productivity in recent years due to skilled worker shortages. They have suggested various strategies for this impact. Later each participant was asked where they thought Pre-fabrication could effectively reduce impact due to skilled worker shortages. Each participant had a different opinion on how prefabrication could

help to increase the productivity. Table 2 summarizes valuable responses identified during the discussion.

Table 2: Interview responses

The more the general contractors understand the designer's side, they are more surprised how iterative our job is and more willing to throw out ideas early.	We try to pull from a preferred group of contractors because they will know how we function and what our response times, which helps with part of shortages.	Less skilled workers are required on site. We can go on site and it is quite quicker.
Pre fabrication was able to help us with efficiency since it was just putting it together once it reaches onsite.	When workers are on site, we can have clear directions for them to move forward.	Reducing On-Site Design Changes
Everyone on the project uses at varying degree, but on a lot of complex projects like laboratories it helps a lot on coordination and productivity	It gives us more control environment for many things like productivity, quality, and safety and uses lesser skilled people with some kind of supervising.	They are able to prefabricate in their shop, from a quality viewpoint, from a schedule viewpoint, production viewpoint, cost viewpoint is to their advantage.
Architects and contractors work on the wall and other details to come up with the best design with a viewpoint of on-site productivity.	On-site, contractors try to substitute much simpler designs and equipment. Plug and play systems like modular VRF (variable refrigerant flow) are more and more popular these days.	Yes, we are using 3D modeling. Its significant help on the field in productivity and cost point of view.
We do not have enough time to review the drawings from consultant engineers and that is an issue.	We rely heavily on subcontractors to join in the making the specific designs if we are short of skilled workers.	Bringing them early helps to do as much prefab as we can, to get as much staging help and working on the details of the drawings.
Because it makes hard for low skilled people to make things that are not used to doing.	First thing is keeping the design details simple, not over complicating the details, not trying to make things too far off the box.	[To increase productivity] there is another big shift into pre-fabrication these days.

All participant responses were matched constantly among other responses, with the objective of consolidating data into repetitive themes. Five out of eight participants discussed pre-

fabrication as a strategy to increase productivity. P1 specifically said “Yes, [with pre-fabrication] less skilled workers are required on site. [Once] we go on site, it is quite quicker. “ Three out of eight suggested early design completion could help increase the productivity. Three out of eight participants expressed simplifying the complexity and repeating the designs could increase productivity in low-skilled workers. Similar responses were grouped together to create a strategy they expressed.

THEME 1: Pre-fabrication

For productivity, participants gave multiple strategies as responses as shown in Table 3. It was identified that six out of eight participants believed that pre-fabrication could improve productivity. P2 noted “*It [Pre-fabrication] gives us more control environment for many things like productivity, quality and safety and we can also use lesser skilled people with some kind of supervising*” during the open-end discussion. P7 noted that pre-fabrication is to their advantage in the management of the productivity of low-skilled workers.

Table 3: Responses with the underlying theme as Prefabrication

	RESPONSE	STRATEGY
P1	Less skilled workers are required on site. We can go on site and it is quite quick.	Pre-fabrication
P2	Prefabrication was able to help us with efficiency since it was just putting it together once it reaches onsite.	Pre-fabrication
P3	It gives us more control environment for many things like productivity, quality, and safety and uses lesser skilled people with some kind of supervising.	Pre-fabrication

P7	They are able to prefabricate in their shop, from a quality viewpoint, from a schedule viewpoint, production viewpoint, cost viewpoint is to their advantage.	Pre-fabrication
P8	[to increase productivity] there is another big shift into pre-fabrication these days.	Pre-fabrication

THEME 2: Early drawing delivery

Three out of eight participants believed early delivery of drawings can help them plan better to increase the productivity. Responses had a link to various other themes, like pre-fabrication. Participant P7 believed early design delivery could help plan better. Table 4 summarizes the responses used in identifying the theme.

Table 4: Responses with the underlying theme as Early design delivery

	Response	Theme
P2	Bringing them early helps to do as much prefab as we can, to get as much staging help and working on the details of the drawings.	Early drawing delivery
P5	When workers are on site, we can have clear directions for them to move forward.	Early drawing delivery
P7	We do not have enough time to review the drawings from consultant engineers and that is an issue.	Early drawing delivery

THEME 3: Repeating/Simplifying Design Elements

Table 5 Responses with the underlying theme as Repeating design elements

	Response	Theme
P6	First thing is keeping the design details simple, not over complicating the details, not trying to make things too far off the box.	Repeating/Simplifying Design Elements
P7	Architects and contractors work on the wall and other details to come up with the best design with a viewpoint of on-site productivity.	Repeating/Simplifying Design Elements
P8	On-site, contractors try to substitute much simpler designs and equipment. Plug and play systems like modular VRF (variable refrigerant flow) are more and more popular these days.	Repeating/Simplifying Design Elements

THEME 4: Repeating Contractors

Table 6: Responses with the underlying theme as Repeating Contractors

	Response	Theme
P6	We try to pull from a preferred group of contractors because they will know how we function and what our response times, which helps with part of shortages.	Repeating Contractors
P2	Because it makes hard for low skilled people to make things that are not used to doing.	Repeating Contractors

THEME 5: 3D Modelling

Table 7: Responses with the underlying theme as 3D modeling

	Response	Theme
P6	Yes, we are using 3D modeling. Its significant help on the field in productivity and cost point of view.	3D Modelling
P2	Everyone on the project uses at varying degree, but on a lot of complex projects like laboratories, it helps a lot on coordination and productivity.	3D Modelling

THEME 6: Involving Sub-Contractors

Table 8: Responses with the underlying theme as Involving sub-contractors

	Response	Theme
P6	We rely heavily on subcontractors to join in the making the specific designs if we are short of skilled workers.	Involving Sub-Contractors
P2	The more the general contractors understand the designer's side, they are more surprised how iterative our job is and more willing to throw out ideas early.	Involving Sub-Contractors

After identifying the themes from the transcripts, they were checked again by going through the audio tapes. It was confirmed that the themes were derived from relevant responses.

4.2.2 Defects

Similar to the question asked for the impact of productivity, participants were asked about their strategy to reduce defects due to low skilled workers. A similar analysis was conducted to identify the strategies expressed by the participants during the interviews. The Table 9 explains the strategies identified through analysis from participant responses.

Table 9: Strategies identified to reduce defects

Theme	Suggested Participants	Total
Pre Fabrication	P3, P7, P8	3
Robust QA/QC from Owner	P1, P2, P3	3
Simplifying/Repeating Design Elements	P6, P7, P8	3
Mockup of Wall	P6, P7	2
Defining Substantial Completion	P1, P3	2

4.2.3 Schedule Delays

A similar to the question was asked if they have identified an increase in schedule delays due to skilled worker shortages. Six out of eight participants responded that they were able to identify the issue. Participants also accepted that the trend has been increasing in recent times. All the participants were also questioned about their strategies to reduce schedule delays due to skilled worker shortages. A similar analysis was conducted to identify the strategies from the responses

during the interviews. The Table 10 explains the strategies identified through analysis from participant responses.

Table 10: Strategies identified to reduce schedule delays

Theme	Suggested Participants	Total
Pre Fabrication	P1, P2, P3, P4, P5, P6, P7, P8	8
Get Subs onboard Early	P1, P2, P4	3
Early Design Completion	P1, P2, P4, P5	4
3D Documentation	P1, P3, P4	3

4.2.4 Reworks

A Similar to the question was asked if they have identified an increase in reworks due to skilled worker shortages. Six out of eight participants responded that they were able to identify the issue. All the participants were then questioned about their strategies to reduce reworks due to skilled worker shortages. A similar analysis was conducted to identify the strategies from the responses during the interviews. The Table 11 explains the strategies identified through analysis from participant responses.

Table 11: Strategies identified to reduce reworks

Theme	Suggested Participants
Pre Fabrication	P3, P7, P8
Robust QA/QC from Owner	P3, P7
Co-Locating/ Discussions	P5, P6, P8

4.3 Phase 2 – Survey

Twenty-six responses were received from the on-line survey. Data received was analyzed to identify any incomplete surveys and were excluded from the data reported in this document. Seven out of twenty-six responses were incomplete and excluded from the analysis. Two of the participants had experience that did not match the experience criteria chosen for participation and were excluded from reporting. Seventeen responses were complete and usable for the analysis.. Figures 7, 8, 9 explain the demographic details of the participants.

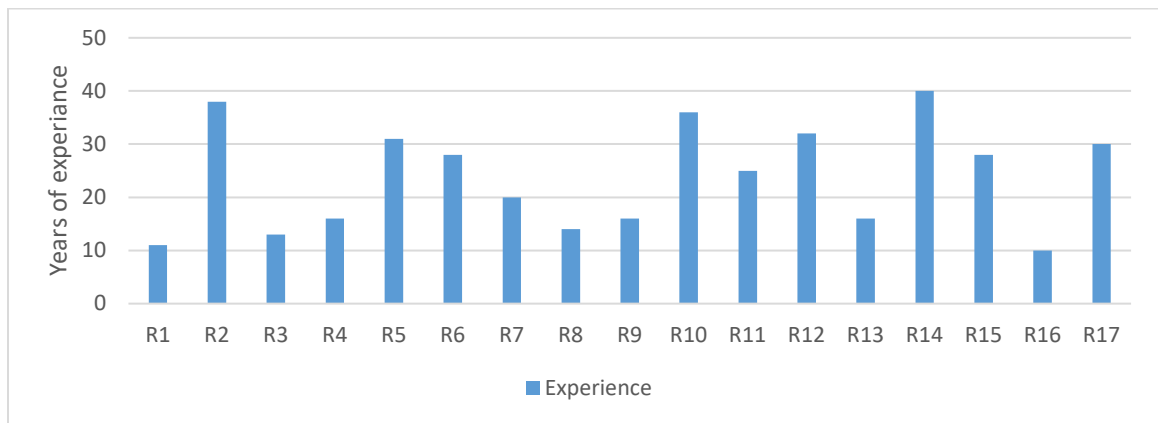


Figure 6: Experience of participants in the construction industry

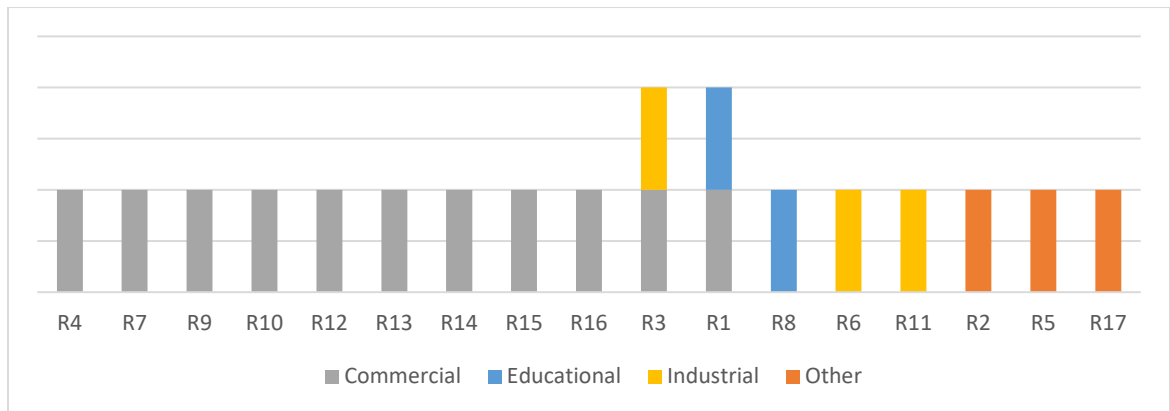


Figure 7: Primary industries of participants

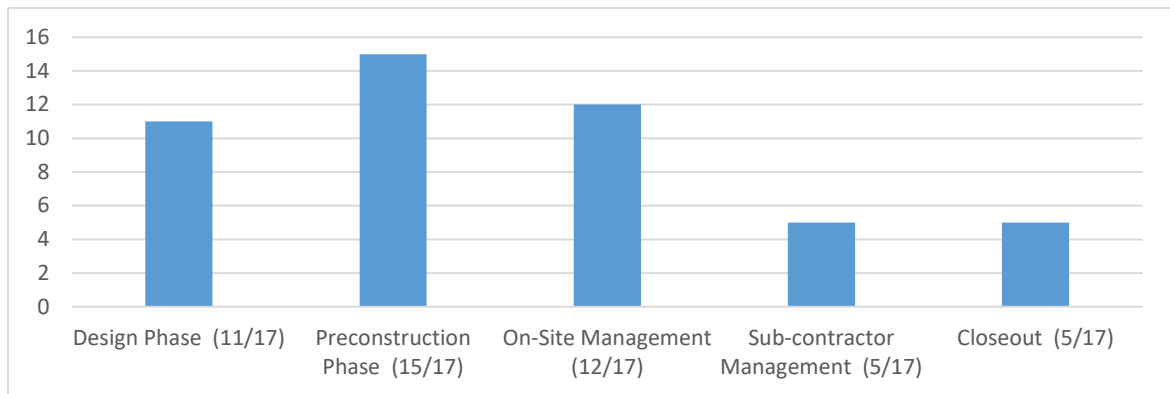


Figure 8: Number of participants involved in each phase of construction

Two out of seventeen participants chose both commercial and educational or industrial as their primary industry. Each strategy is questioned against each impact to identify the effectiveness towards respective impact.

4.4 Results of Survey

This section aimed to report the perception of the effectiveness of strategies by each of the respondents. Each respondent reported his or her perception of a set of seven strategies separately. The steps followed to identify the effectiveness of each strategy is reported below in Figure 10.

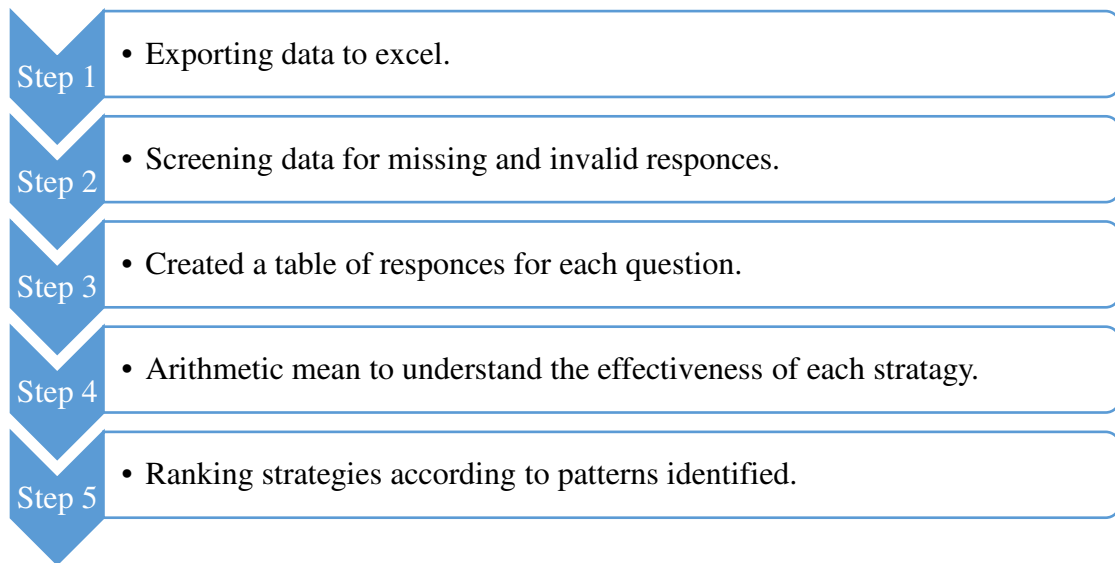


Figure 9: Process of survey analysis

The detailed process followed for the analysis of productivity is reported for reference. Authors followed the same method for the analysis of each question.

4.4.1 Productivity

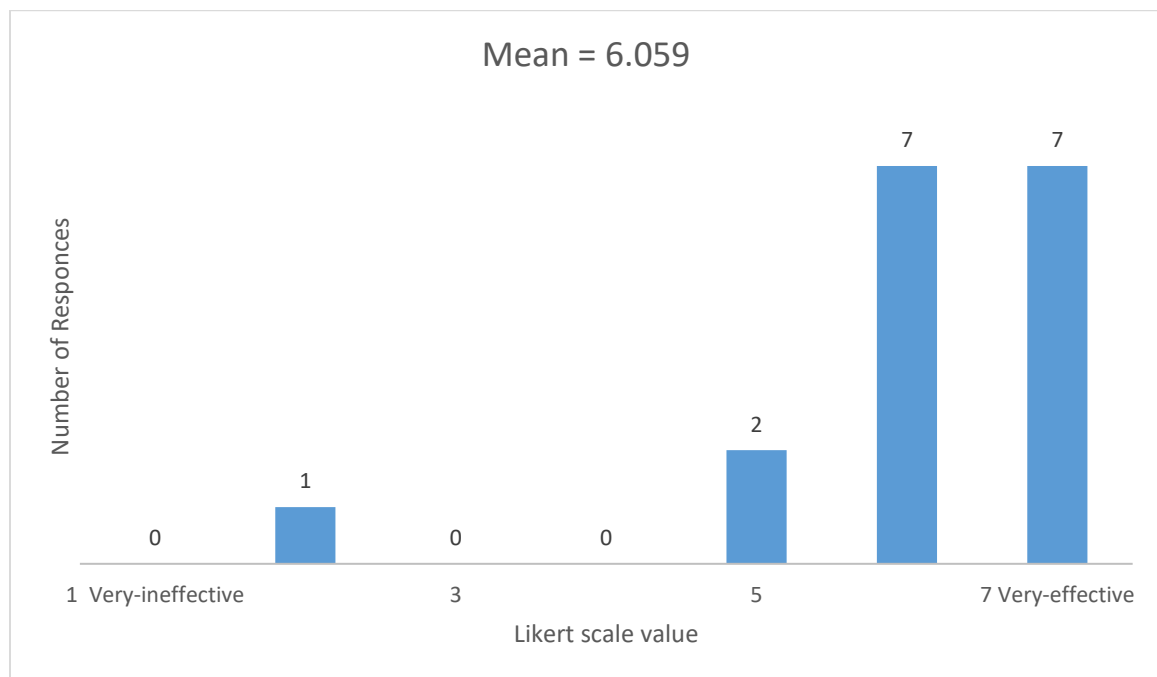
Seven possible strategies were identified during the personal interviews to reduce productivity loss due to skill shortages in the construction industry. The survey consisted questions Q7 to Q13 related to the productivity loss. A similar question structure with a change of strategy was used. These seven questions helped to record the effectiveness of each strategy for the specific impact.

THEME 1: Pre-fabrication

The first question was structured as “*How effective can pre-fabrication be to reduce the loss of productivity due to skilled worker shortages?*” to understand the perception of the respondent. A majority of participants (94%) stated that pre-fabrication could be an effective

strategy to reduce the impact of skill shortages in the construction industry. While no one chose to be neutral, only one participant responded prefabrication could be ineffective to reduce the productivity loss due to skill shortages. The arithmetic mean of all the responses on a Likert scale of one to seven was reported as 6.059. Table 12 shows the distribution of responses across the Likert scale for the question Q7.

Table 12: Responses for Pre-fabrication as a strategy to increase productivity

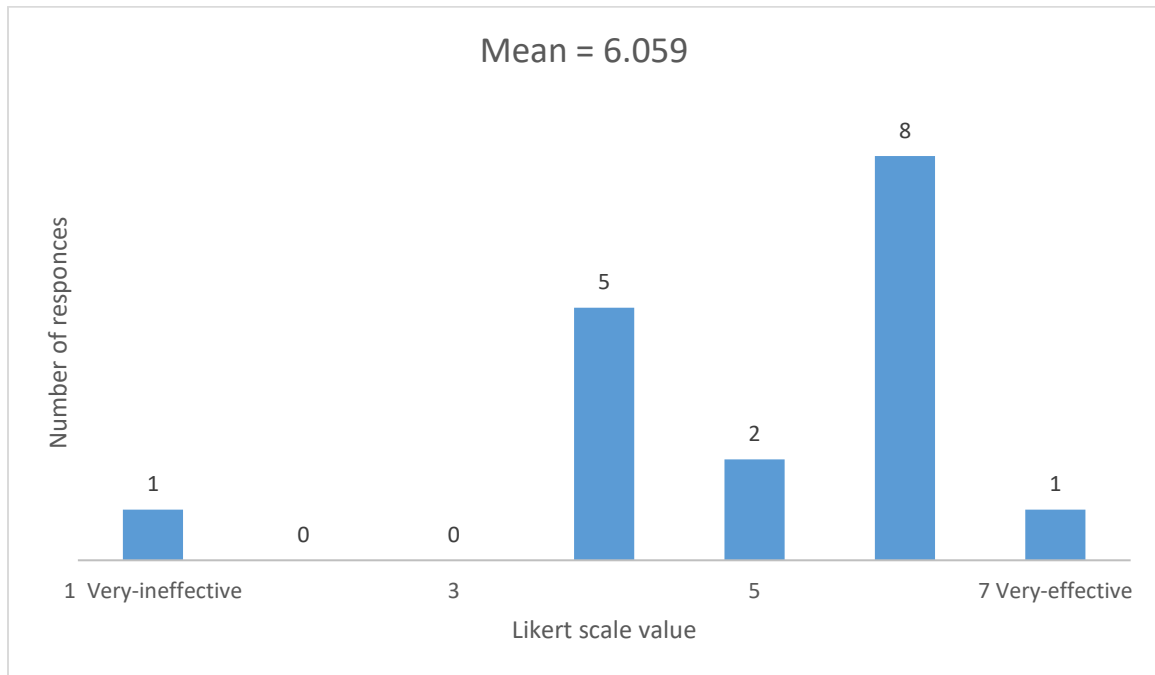


THEME 2: Early design completion

The second question was “*How effective can early design completion be to reduce the loss of productivity due to skilled worker shortages?*” to understand the perception of the respondent. A majority of participants (64%) stated that early design completion could be an effective strategy to reduce the impact of skill shortages in the construction industry. While no one responded that it

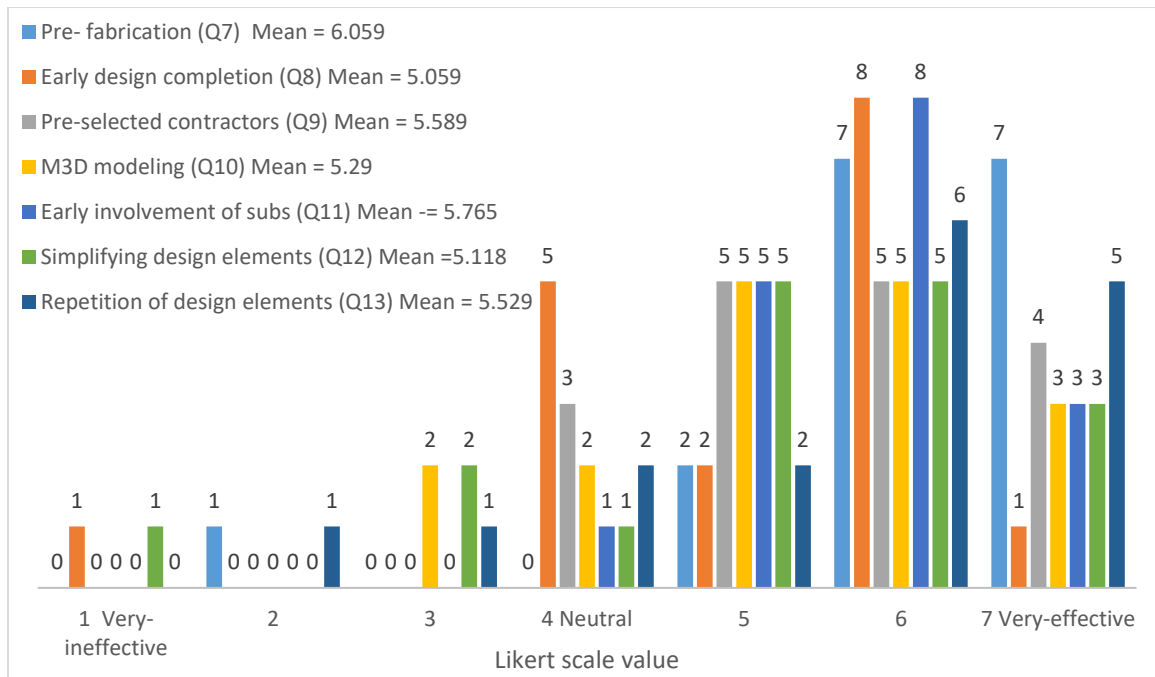
could be ineffective, five participants chose to be neutral towards the statement. One participant even responded that it could be very ineffective. The arithmetic mean of all the responses on a Likert scale of one to seven was as 5.059. Table 13 shows the distribution of responses across the Likert scale for the question Q8.

Table 13: Responses to early design completion as a strategy to increase productivity



A similar method was used to derive the following figure from the responses received. Table 14 shows the distribution of responses across the Likert scale for each question from Q7 to Q13.

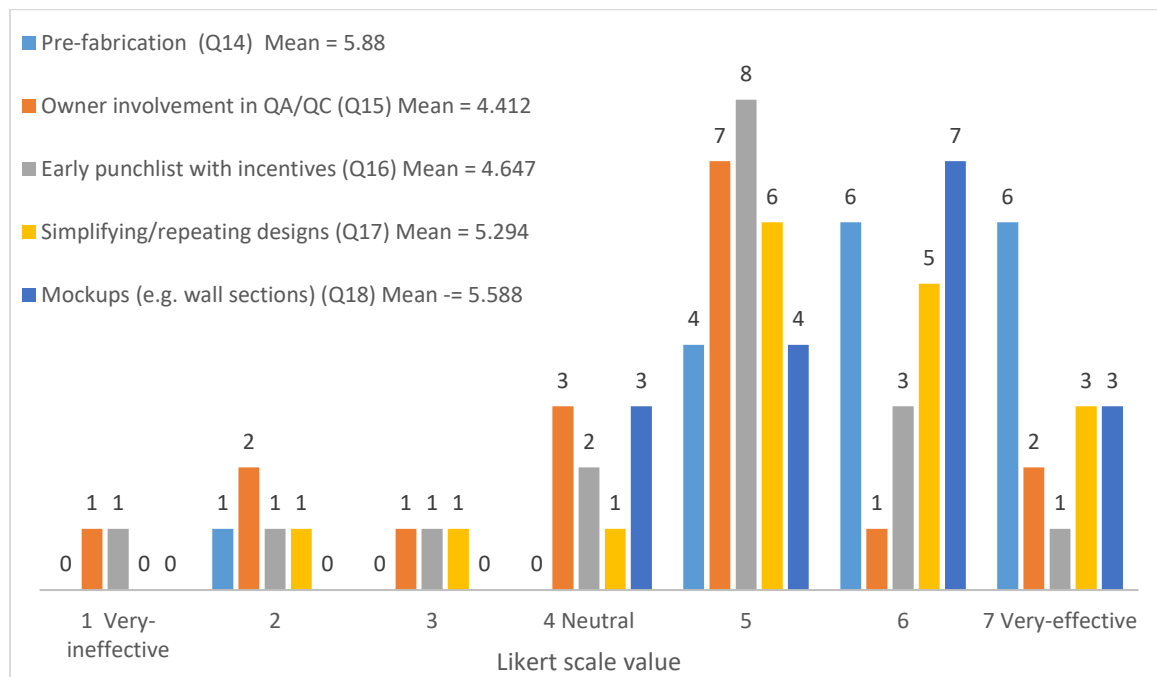
Table 14: Responses to each strategy to increase productivity



4.4.2 Construction defects

A set of similar questions were asked to understand the effectiveness of the strategies identified through the interviews to reduce defects. Participants responded on a Likert scale of one to seven for the question Q14 to Q18. Table 15 shows the distribution of responses across the Likert scale for each question from Q14 to Q18.

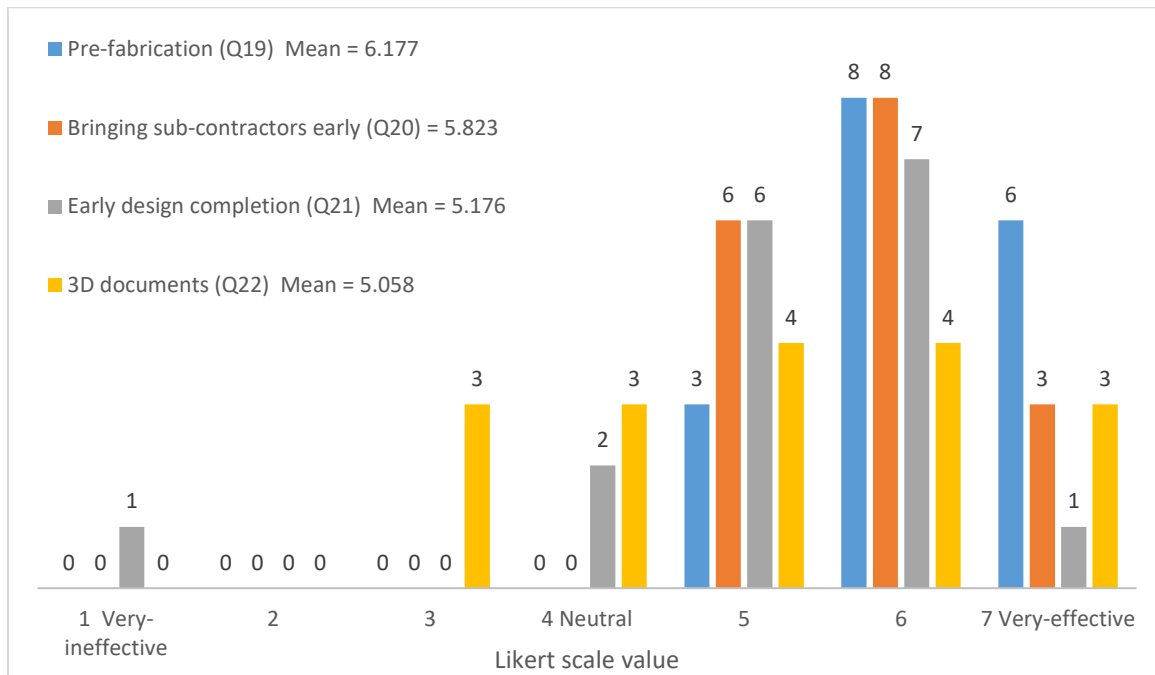
Table 15: Responses to each strategy to decrease defects



4.4.3 Schedule Delays

A set of similar questions were asked to understand the effectiveness of the strategies identified through the interviews to reduce schedule delays. Participants responded on a Likert scale of one to seven for the question Q19 to Q22. Table 16 shows the distribution of responses across the Likert scale for each question from Q19 to Q22.

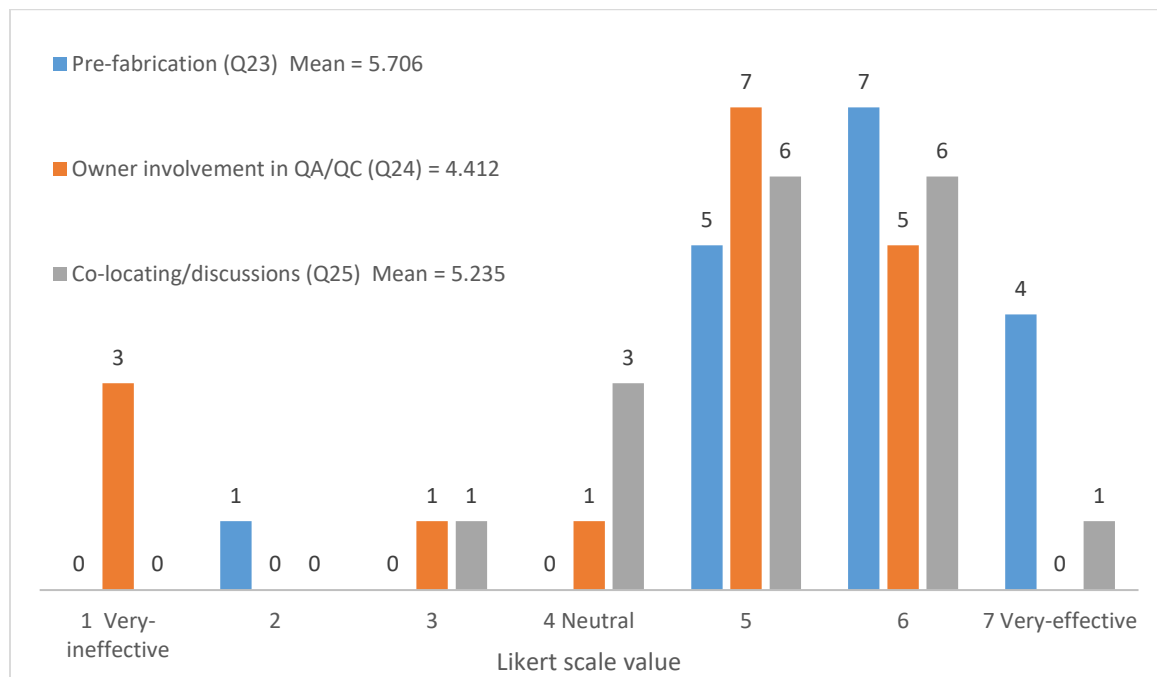
Table 16: Responses to each strategy to decrease schedule delays



4.4.4 Rework

A set of similar questions were asked to understand the effectiveness of the strategies identified through the interviews to reduce rework. Participants responded on a Likert scale of one to seven for the question Q23 to Q25. Table 17 shows the distribution of responses across the Likert scale for each question from Q23 to Q25.

Table 17: Responses to each strategy to decrease reworks



4.5 Discussion

The purpose of this study was to explore the effective strategies implemented in the construction industry in response to the skilled worker shortages experienced. To analyze the findings from two phases of the study, research questions are revisited here which are:

1. What are the strategies practiced in the industry to reduce the impacts of skilled workforce shortages?
2. How effective are the strategies identified through the interviews to reduce the negative impacts of skill shortages on the construction industry?

Data from both eight interview participants (qualitative) and seventeen survey participants (quantitative) was analyzed to find the confirmations. Data from the survey was not further analyzed based on demographics due to low response rate. Data from interviews was analyzed using descriptive statistics only

The highest number of occurrence during interviews happened for prefabrication as a strategy for reducing schedule delays. All the interview responses had this theme reported at least once during the interview. Participant P2 specifically said, “In one of the projects, when we knew that resources are going to be limited, it [pre-fabrication] helped in sticking to the schedule”. Others reported that pre-fabrication helped them achieve projects tight schedules and they had met with their companies to increase the usage. One participant P8 clearly stated ” The amount of schedule savings was incredible, it costs little more but it was almost mind-blowing how quick they put together” as a response to question asked if prefabrication could help reduce the impacts due to skill shortages. Similar to the highest repetition during the interviews, the highest arithmetic mean was reported in the survey results for the same strategy to reduce schedule delays. A mean

value of 6.18 was reported in the survey. None of the participants chose to be neutral and all the seventeen participants responded with an acceptance.

Similar patterns were seen in the responses during both phases for prefabrication as a strategy to increase the productivity of construction workers. This is the only other strategy that achieved arithmetic mean above six on the Likert scale responses during the survey. Five out of eight participants in the interviews reported this. Pre-fabrication as a strategy also has received a mode of seven among the survey participants. As many as seven out of seventeen participants reported this as “very effective” means to decrease the productivity loss due to skilled workforce shortages. Seven out of seventeen also accepted that it could be “effective” to increase the productivity of the construction industry. Only one out of seventeen participants reported it as “ineffective”, while no one remained neutral. Table 18 explains the importance of each strategy depending on the acceptance given in both interviews and the survey.

Table 18: Rankings of strategies with respect to impacts

	Strategy - Impact	Mean Value	Repetitions
1	Pre-fabrication - schedule delays	6.1765	8
2	Pre-Fabrication - productivity	6.0588	5
3	Pre-fabrication - construction defects	5.8824	3
4	Bringing sub-contractors early - schedule delays	5.8235	3
5	Early involvement of sub - productivity	5.7647	3
6	Pre-fabrication - rework	5.7059	3
7	Pre-selected contractors - productivity	5.5882	3

8	Mockups (e.g. wall sections) - construction defects	5.5882	3
9	Repetition of design elements - productivity	5.5294	3
10	3D modeling - productivity	5.2941	2
11	Simplifying/repeating designs - construction defects	5.2941	3
12	Co-locating/discussions - rework	5.2353	3
13	Early design completion - schedule delays	5.1765	4
14	Simplifying design elements - productivity	5.1176	3
15	Early design completion - productivity	5.0588	2
16	3D documents - schedule delays	5.0588	3
17	Early punchlist with incentives - construction defects	4.6471	2
18	Owner involvement in QA/QC - construction defects	4.4118	3
19	Owner involvement in QA/QC - rework	4.4118	2

A similar acceptance is observed with the overall distribution of the means and the number of interview participants that expressed the strategy. Early design completion to reduce schedule delays is the only exception that was rated low by the survey participants while four among the eight participants responded that this was one of the strategies they would use to reduce schedule delays. Even though specific reason could not be pointed out, reading the transcripts from the interviews gave an insight into the possible perception difference. Interview responses focused more towards the idea of finishing the design early to reduce the schedule delays and deviated from the purpose of the study to analyze the strategies to reduce the schedule delays caused by skilled workforce shortages.

All participant responses were matched constantly among survey responses, with the objective of analysis for most effective strategies. Four out of top six strategies reported prefabrication as a strategy to reduce the impact of skilled workforce shortage. Prefabrication was the highest accepted a strategy for all the impacts recognized with arithmetic means of 6.18, 6.06, 5.89, and 5.71 for schedule delays, productivity, construction defects, rework respectively. Similarly in the qualitative study, prefabrication had a repetition at the rate of eight, five, three and three for schedule delays, productivity, construction defects, rework respectively. This indicates that prefabrication has been accepted by more participants as a better solution than the others strategies examined.

Bringing sub-contractors early was the second most accepted strategy. It was accepted as the second most effective strategy for decreasing schedule delays and increasing productivity of construction workers. Participant P4 specifically said, “We rely heavily on subcontractors to join in the making the specific designs if we are short of skilled workers”. Hence, in the skilled workforce shortage areas, it emphasizes the importance of selecting and involving the subcontractors early.

CHAPTER 5: SUMMARY AND FUTURE RESEARCH

5.1 Conclusion

The construction industry consists of complex organizations experiencing swift changes, with diversified offerings, that are widely distributed and require a variety of skilled units. One of the major challenges in construction industry includes recruiting and passing critical knowledge to the next generations (Sowers & Woody, 2006). With increasing skilled worker shortages, the industry is recruiting more low skilled workers. There are existing techniques to train workers and improve their skills. Therefore, the primary objective of this research was to identify effective strategies at pre-construction stage to reduce the impacts of skilled worker shortages in the construction industry. Identifying strategies to reduce the impacts allows contractors and designers to better strategize in case of markets with skilled worker shortages. These strategies will also allow contractors to work with owners and make construction decisions that are not motivated by misinterpretation, bias, or lack of awareness.

Literature was gathered from existing literature to identify the impacted areas due to skilled worker shortages. Telephone interviews were conducted to discover the potential strategies from the industry experts. A survey instrument was developed and piloted by an experienced researcher. The survey instrument was refined and distributed through DBIA email list. Data from both the methods was analyzed to identify the effective strategies. The data from telephone interviews were supplemented by the survey.

Majority of the telephone interview participants had experienced the impacts of skilled worker shortages in construction and attributed to the increase in recent times. Both the interview and survey professionals complemented each other in most strategies. The highest rate of acceptance from the interviews was received for the prefabrication strategy to reduce the impacts due to skilled workforce shortages.

Schedule delays due to skilled workforce shortages can be effectively controlled going for prefabrication, involving subcontractors early and early design completion in respective order. Going for 3D documents can be least effective among the chosen strategies to improve schedule delays according to the participants in this study. Productivity loss due to skilled workforce shortages could most effectively improve by going for prefabrication, early subcontractor involvement and repeating design elements. Construction defects due to skilled workforce shortages could reduce by going for prefabrication, setting up mockups and repeating design elements according to the research performed.

After all the data analyzed, it is safe to assume that schedule delays, productivity and construction defects have a better chance of improvement through the respective strategies identified when compared to the rework and the strategies identified. The general trends observed in the data analysis suggested prefabrication could be the most effective strategy to reduce the impact of skilled workforce shortages. These findings have their own limitations due to the small sample size for a quantitative and selective sample for qualitative.

5.2 Limitations and Future Research

The study was initially undertaken when the researcher discovered that the topic had not been explored much previously. Most of the previous studies explored training low skilled workers

to reduce the impacts. It was therefore chosen to study the alternative strategies to mitigate the impacts. This was done in two stages, First; telephone interviews were conveniently sampled due to the time constraint. Majority of the participants were located in one region in a state, Fort Collins and Denver region in Colorado. Majority of participants were employed in pre-construction phases of construction. Only three participants had involved in onsite construction management. Given both geographic and convenient sampling limitations, opinions might have had an underlying bias towards the topic. This makes it difficult to draw a definitive conclusion about the possible effective strategies identified in the interviews. The low response rate for the electronic survey indicates the need for better sample size to understand the effectiveness.

Participants for the electronic survey were all associated with DBIA (Design-Build Institute of America). The low response rate could have had a potential bias in the responses achieved. This makes it difficult to generalize the research findings to the whole construction industry.

The future studies should be larger and diverse in selecting the survey participants. It is necessary to recruit more varied demographic participants in future to avoid possible bias. It is, therefore, necessary for other researchers to continue examining the effective strategies used in the construction industry with larger population samples. Five years later, it will be interesting to conduct the same survey and identify the new strategies emerging with ever-increasing skilled workforce shortages.

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APPENDICES

Appendix 1

Consent form

a.

DBIA Professional,

My name is Eeswar Atluri and I am a researcher at Colorado State University in the Department of Construction Management. We are conducting a research study on strategies used by designers/contractors to reduce the impact of skilled worker shortages in the construction industry. The title of our project is “Strategies Implemented by Designers and Contractors to Reduce the Impact of Skilled Worker Shortages.” The Principal Investigator is Dr. Kelly Strong, Dept. of Construction Management, CSU and I am the Co-Principal Investigator.

We would like you to take an online survey. Participation will take approximately fifteen minutes. Your participation in this research is voluntary. If you decide not to participate in the study, you may withdraw your consent and stop participation at any time without penalty.

We will be collecting information on your experience and area of expertise. When we report and share the data with others, we will combine the data from all participants. We will keep your data confidential; your name and data will be kept separately accessible only to the research team. We hope to gain more knowledge on the strategies that can be used by the project teams to reduce the impact of low-skilled workers at the design stage. A summary of our findings will be made available through various DBIA outlets at the completion of our study.

It is not possible to identify all potential risks in research procedures, but the researcher(s) have taken reasonable safeguards to minimize any known and potential (but unknown) risks.

If you have any questions about the research, please contact Eeswar Atluri at atluri@colostate.edu or Dr. Kelly Strong at Kelly.Strong@colostate.edu. If you have any questions about your rights as a volunteer in this research, contact the CSU IRB at: RICRO_IRB@mail.colostate.edu; 970-491-1553.

Dr. Kelly Strong
(PI title)

Eeswar Atluri
(Co-PI)

a. To indicate your willingness to participate in this research and to continue on to the survey, please select I consent:

- ☐ I consent
☐ I do not consent

Background

Q1. What is your current title?

Q2. How many years of experience do you have in the design and construction industry?

Q3. What is your primary role in the design and construction industry?

- ☐ Architect
☐ Contractor
☐ Engineer
☐ Other

Q4. What is your primary market sector?

- ☐ Commercial
☐ Industrial
☐ Multifamily
☐ Educational
☐ Other

Q6. What stages of construction are you involved in?

- ☐ Architectural Design
☐ Pre-Construction

- ☐ Design Management
- ☐ On-site construction management
- ☐ Sub-contracting
- ☐ Closeout
- ☐ Other

Productivity

Q7. How effective can pre-fabrication be to reduce the loss of productivity due to skilled worker shortages?

Very Ineffective	.	.	Neutral	.	.	Very Effective
1	2	3	4	5	6	7

Q8. How effective can early design completion be to reduce the loss of productivity due to skilled worker shortages?

Very Ineffective	.	.	Neutral	.	.	Very Effective
1	2	3	4	5	6	7

Q9. How effective can the use of pre-selected contractors (e.g. repeat builders) be to reduce productivity loss due to skilled worker shortages?

Very Ineffective	.	.	Neutral	.	.	Very Effective
1	2	3	4	5	6	7

Q10. How effective can 3D modeling be to reduce productivity loss due to skilled worker shortages?

Very Ineffective	.	.	Neutral	.	.	Very Effective
1	2	3	4	5	6	7

Q11. How effective can early involvement of subcontractors in the design phase be to reduce productivity loss due to skilled worker shortages?

Very Ineffective	.	.	Neutral	.	.	Very Effective
1	2	3	4	5	6	7

Q12. How effective can simplifying design elements be to reduce productivity loss due to skilled worker shortages?

Very Ineffective	.	.	Neutral	.	.	Very Effective
1	2	3	4	5	6	7

Q13. How effective can repetition of design elements be to reduce productivity loss due to skilled worker shortages?

Very Ineffective	.	.	Neutral	.	.	Very Effective
1	2	3	4	5	6	7

Defects

Q14. How effective can pre-fabrication be to reduce construction defects due to skilled worker shortages?

Very Ineffective	.	.	Neutral	.	.	Very Effective
1	2	3	4	5	6	7

Q15. How effective can owner involvement in QA/QC be to reduce construction defects due to skilled worker shortages?

Very Ineffective	.	.	Neutral	.	.	Very Effective
1	2	3	4	5	6	7

Q16. How effective can early punchlist with incentives for sub-contractors be to reduce construction defects due to skilled worker shortages?

Very Ineffective	.	.	Neutral	.	.	Very Effective
1	2	3	4	5	6	7

Q17. How effective can simplifying/repeating designs be to reduce construction defects due to skilled worker shortages?

Very Ineffective	.	.	Neutral	.	.	Very Effective
1	2	3	4	5	6	7

Q18. How effective can mockups (e.g. wall sections) be to reduce construction defects due to skilled worker shortages?

Very Ineffective	.	.	Neutral	.	.	Very Effective
1	2	3	4	5	6	7

Schedule delays

Q19. How effective can pre-fabrication be to reduce schedule delays due to skilled worker shortages?

Very Ineffective	.	.	Neutral	.	.	Very Effective
1	2	3	4	5	6	7

Q20. How effective can bringing sub-contractors onboard early be to reduce schedule delays due to skilled worker shortages?

Very Ineffective	.	.	Neutral	.	.	Very Effective
1	2	3	4	5	6	7

Q21. How effective can early design completion be to reduce schedule delays due to skilled worker shortages?

Very Ineffective	.	.	Neutral	.	.	Very Effective
1	2	3	4	5	6	7

Q22. How effective can 3D documents be to reduce schedule delays due to skilled worker shortages?

Very Ineffective	.	.	Neutral	.	.	Very Effective
1	2	3	4	5	6	7

Reworks

Q23. How effective can pre-fabrication be to reduce rework due to skilled worker shortages?

Very Ineffective	.	.	Neutral	.	.	Very Effective
1	2	3	4	5	6	7

Q24. How effective can owner involvement in QA/QC be to reduce rework due to skilled worker shortages?

Very Ineffective	.	.	Neutral	.	.	Very Effective
1	2	3	4	5	6	7

Q25. How effective can co-locating/discussions be to reduce rework due to skilled worker shortages?

Very Ineffective	.	.	Neutral	.	.	Very Effective
1	2	3	4	5	6	7

Strategies

Q26. Where do you think pre-fabrication will be most helpful in mitigating impacts due to skilled worker shortages? (Select multiple if applicable)

- ☐ Productivity
- ☐ Defects
- ☐ Schedule delays
- ☐ Reworks
- ☐ Other

Q27. Where do you think simplifying/repeating design elements will be most helpful in mitigating impacts due to skilled worker shortages? (Select multiple if applicable)

- ☐ Productivity
- ☐ Defects
- ☐ Schedule delays
- ☐ Reworks
- ☐ Other

Q28. Where do you think 3D documents will be most helpful in mitigating impacts due to skilled worker shortages? (Select multiple if applicable)

- ☐ Productivity
- ☐ Defects
- ☐ Schedule delays
- ☐ Reworks
- ☐ Other

Q29. Where do you think early design completion will be most helpful in mitigating impacts due to skilled worker shortages? (Select multiple if applicable)

- ☐ Productivity
- ☐ Defects
- ☐ Schedule delays
- ☐ Reworks
- ☐ Other

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Consent for Participation in Interview Research

Title: Effective Strategies to Reduce the Impacts of Skilled Workforce Shortage

You have been requested to take part in a research study about the strategies used by designers/contractors to reduce the impact of skilled workforce shortages in construction industry. The main purpose of this focus group is to identify the strategies at pre construction stage that can reduce the impacts due to skill shortages. You have been selected as you have more than 10 years of related experience in the construction industry. Researchers would like to you to discuss about the techniques you have implemented in your experience to reduce the impacts identified in our literature study.

This discussion is voluntary, you do not have to take part if you do not want to. If any part of our questions or the discussion make you feel uncomfortable, you do not have to answer them. You may also leave the group at any time for any reason. The discussion will be audio taped but your privacy will be protected. Your name and any personal identification data will be accessible to the researchers only, it will not be used in any publications.

While there are no direct benefits to you, we hope to gain more knowledge on the strategies that can be used by designers to reduce the impact of skilled workforce shortages at design stage. It is not possible to identify all potential risks in research procedures, but the researcher(s) have taken reasonable safeguards to minimize any known and potential (but unknown) risks.

If you have any questions about the research, please contact Eeswar Atluri at atluri@colostate.edu or Dr. Kelly Strong at Kelly.Strong@colostate.edu. If you have any questions about your rights as a volunteer in this research, contact the CSU IRB at: RICRO_IRB@mail.colostate.edu; 970-491-1553.

Please write your name below and check yes or no. If you want to take part Sign your name at the bottom.

_____ Yes, I would like to take part in the focus group.

_____ No, I would not like to participate in the focus group.

Signature: _____

Name:

Dr. Kelly Strong
(PI title)

Eeswar Atluri
(Co-PI)